



The UK MoD Power Sources Programme

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Joint grant scheme-EPSRC/MoD funded

- Cranfield Univ - 3D catalyst/membrane structures for FCs - PEMFC
- Imperial College - 3D catalyst/membrane structures for FCs - PEMFC
- Imperial College - Optimisation of Sc-stabilised zirconia - SOFC
- Imperial College - Intermediate temperature SOFC
- Imperial College - Catalyst development for DMFC
- Loughborough Univ-Thin SOFC electrolytes
- Newcastle Univ - New anodes for DMFC
- Newcastle Univ - Novel catalysts/membranes for FCs - DMFC/PEMFC
- Newcastle Univ - Novel air and water disinfection
- Nottingham Univ-Hydrogen storage in carbon
- St Andrews Univ - Optimisation of Sc-stabilised zirconia - SOFC

Corporate (strategic) research

- The alkaline polymer electrolyte membrane fuel cell
 - direct methanol **and direct sodium borohydride options**
- Advanced lithium batteries-primary and secondary
- Hydrogen storage in carbon nano-structures
- Fuel cell-powered field generator/battery charger

Just finished, but valuable technology needing further devt:

- Advanced thermal reserve batteries
 - **75 % decrease in activation time. New, high energy cathodes identified**
- High temperature proton conducting fuel cell (HTPCFC) - **ONR take-up**
 - **Operate at 250-500 C but compete with SOFC at 850-1,000 C**

Applied research programme

- Devt of pre-reformer for marine gas oil (MGO)
 - Ship service generator application. Completed programme.
- Advanced power sources for SF
 - advanced Li-carbon monofluoride primary pouch battery
 - advanced lithium rechargeable pouch battery
- Man-portable power source for FIST
 - 2D fuel cell
 - advanced hydrogen storage/generation
- Alternative power sources for underwater vehicles
- Regenesys - marinisation issues - Priority Pathfinder
 - ends December 2001

Project support

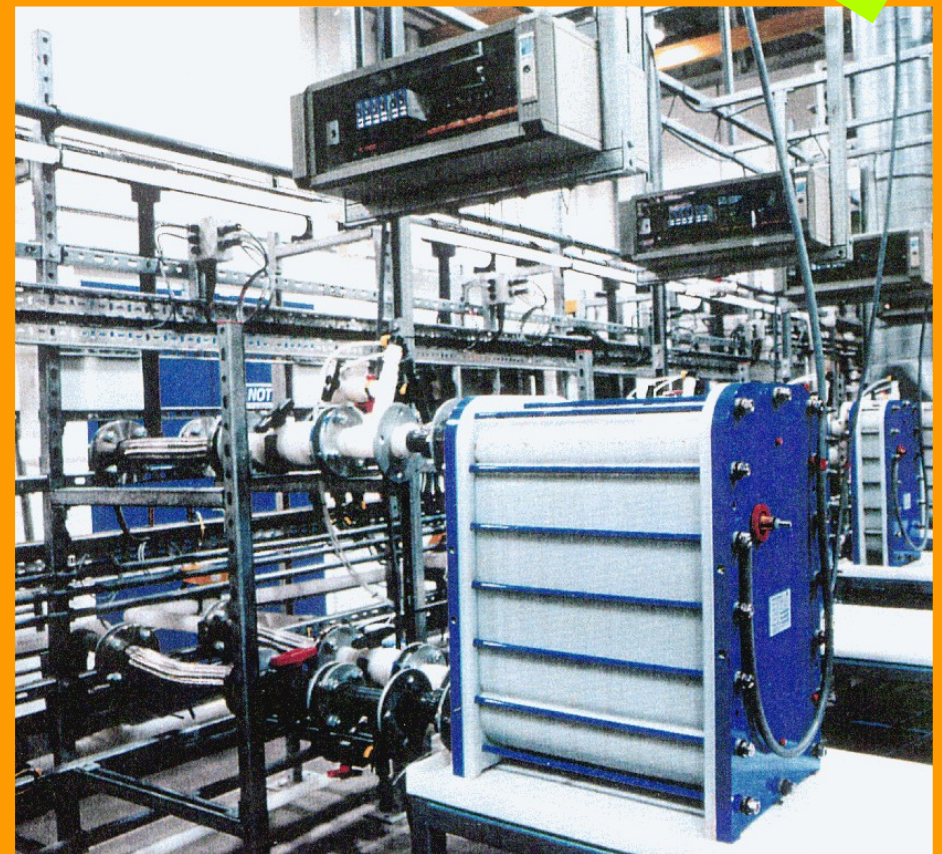
- 6 kW, city diesel-fuelled, fuel cell generator
- Evaluation of energy storage options for submarines
 - valve regulated lead acid batteries (VRLAs)
 - Zebra - high temperature sodium/nickel chloride
 - Regenesys
 - lithium-ion (watching brief)
- Electric ship STDF
 - includes Regenesys energy storage option
 - assessed 2002-2004



PATHFINDER Successes in Sea

Priority
Pathfinder

- Innogy TVL + Dstl
- Commercial regenerative fuel cell technology
- Emergency power for ships and submarines
- Potentially low through life cost
- 20 year cell life prediction
- Fully automated
- No gassing
- State of charge easily measured
- Fit and forget whilst at sea

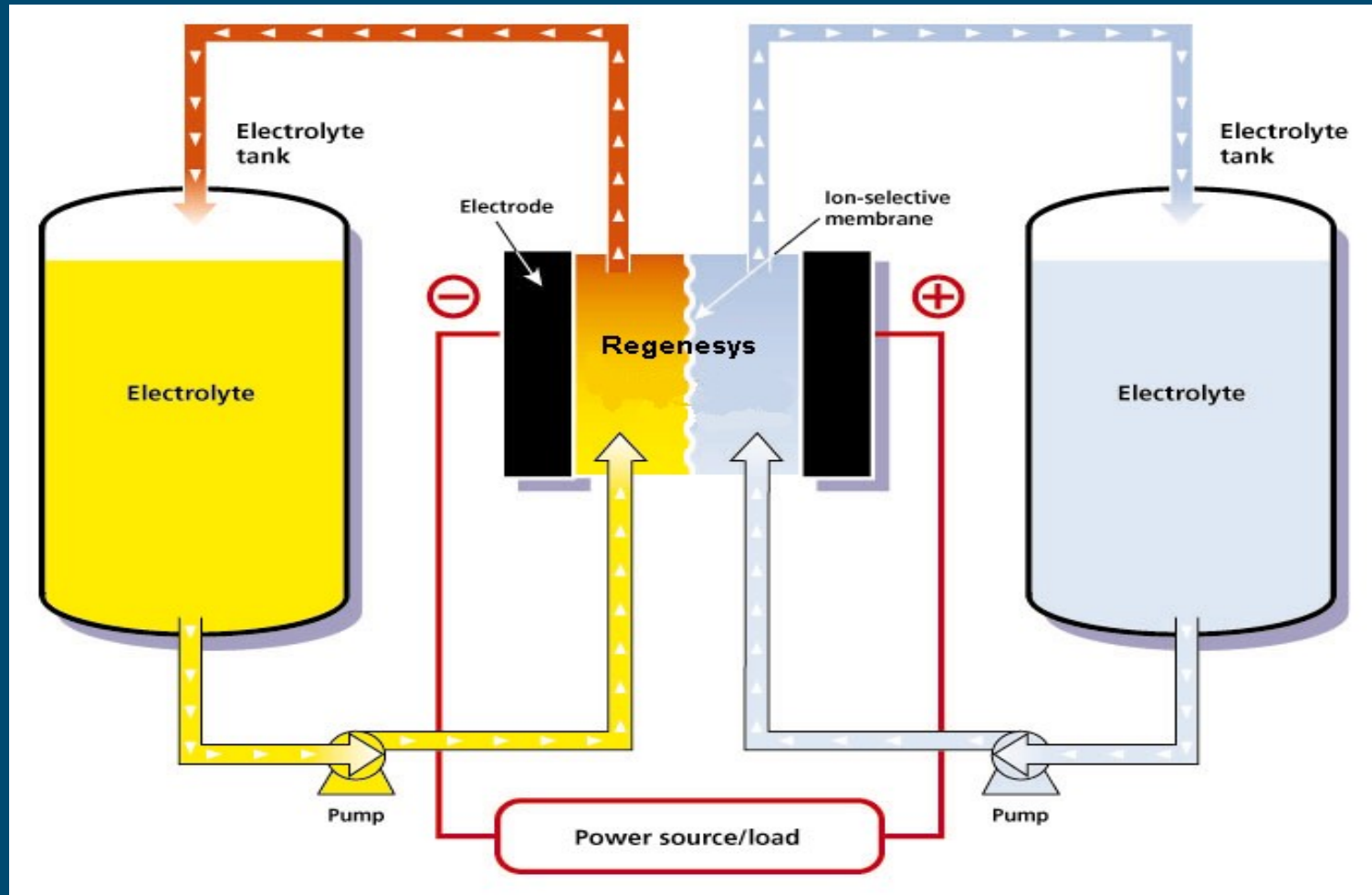


Innogy TVL's regenerative fuel cell

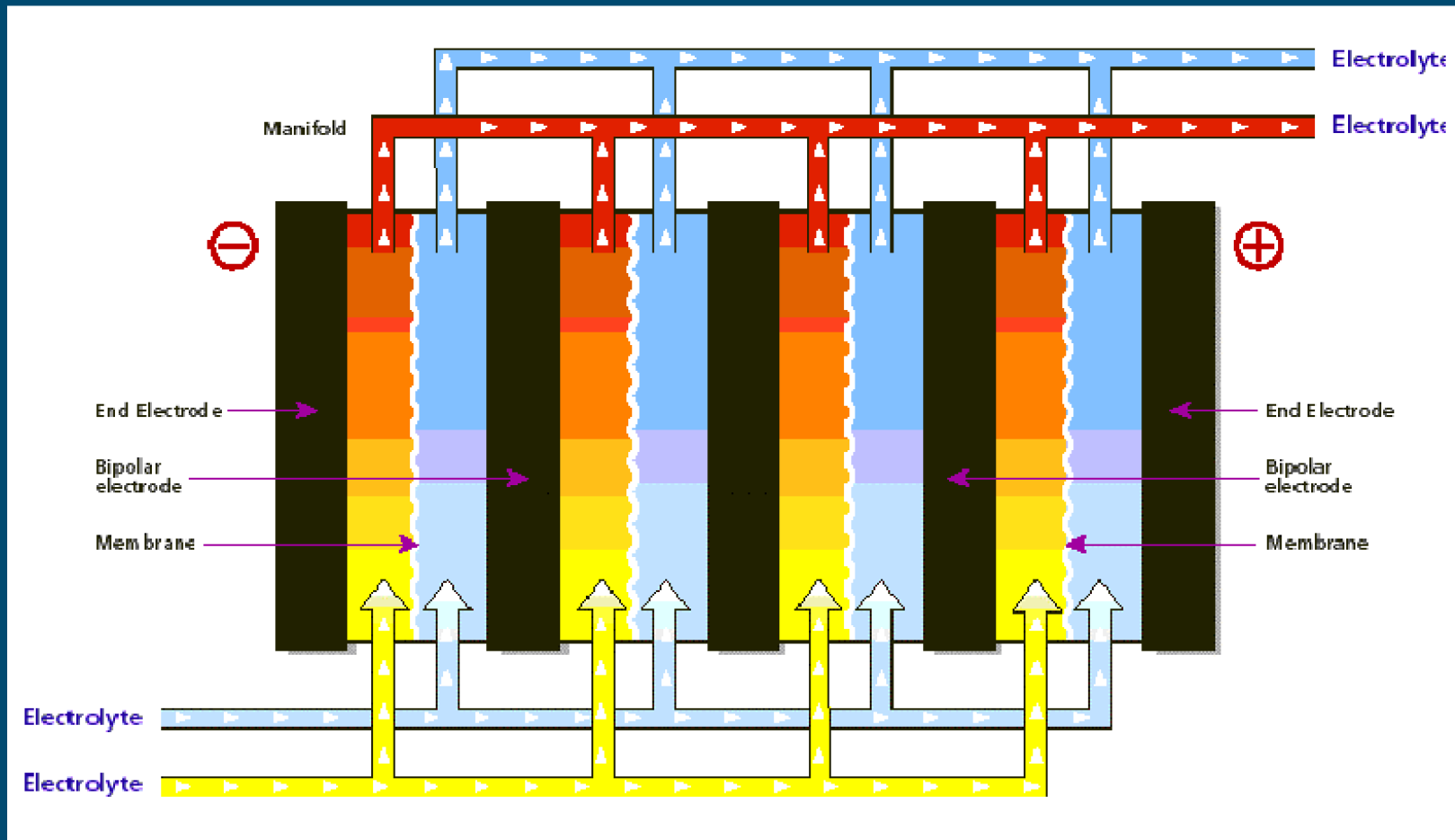


- Regenesys™ - stationary energy storage for utility scale applications
- Modular with Bipolar construction
- Energy and power independently variable
 - more/larger modules = more power
 - more electrolyte = more energy storage

Schematic of Regenesys



Regenesys bipolar module arrangement



Regenesys modules



Target to double power density and triple energy density

Regenesys XL module for Marigenix™



DMFCs - acid vs. alkali

- DMFCs employing proton conducting membranes
 - high methanol crossover rate = dilute solutions/low energy density
 - catalysis of electrode reactions are sluggish in acidic media. Base metal catalysts corrode.
- DMFCs employing anion conducting membranes
 - lower methanol crossover rate than protonic membranes
 - electrode kinetics in alkali faster than in acid = base metal catalysts possible - do not corrode
 - DMFCs employing anion conducting polymers offer potential for higher power density

Acid DMFC

- Reactions:

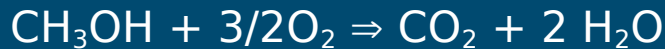
Anode



Cathode



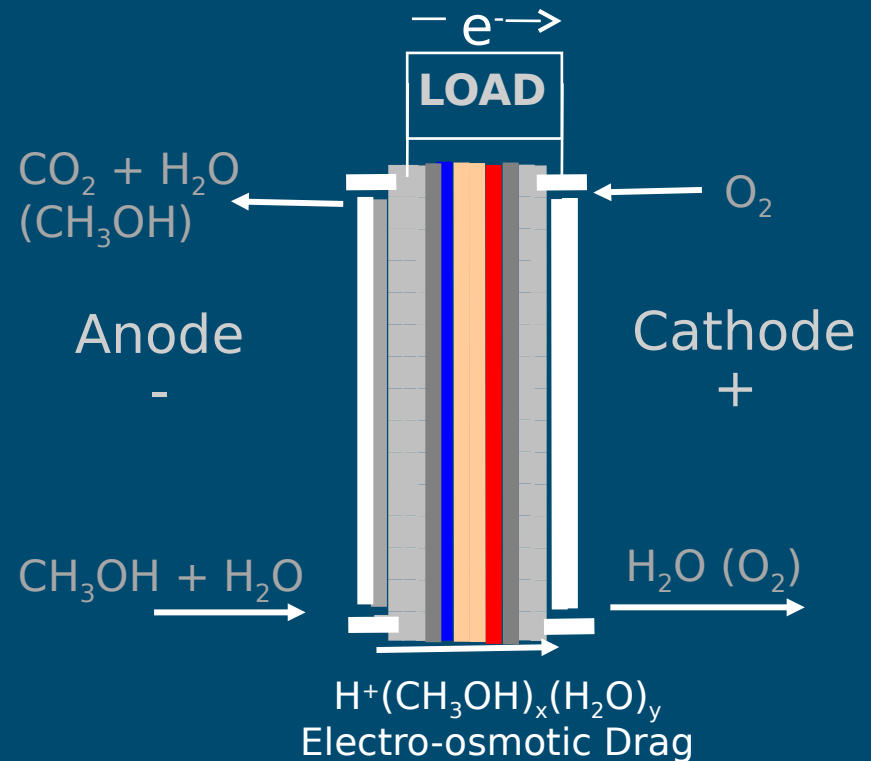
Overall



- Electrolyte:

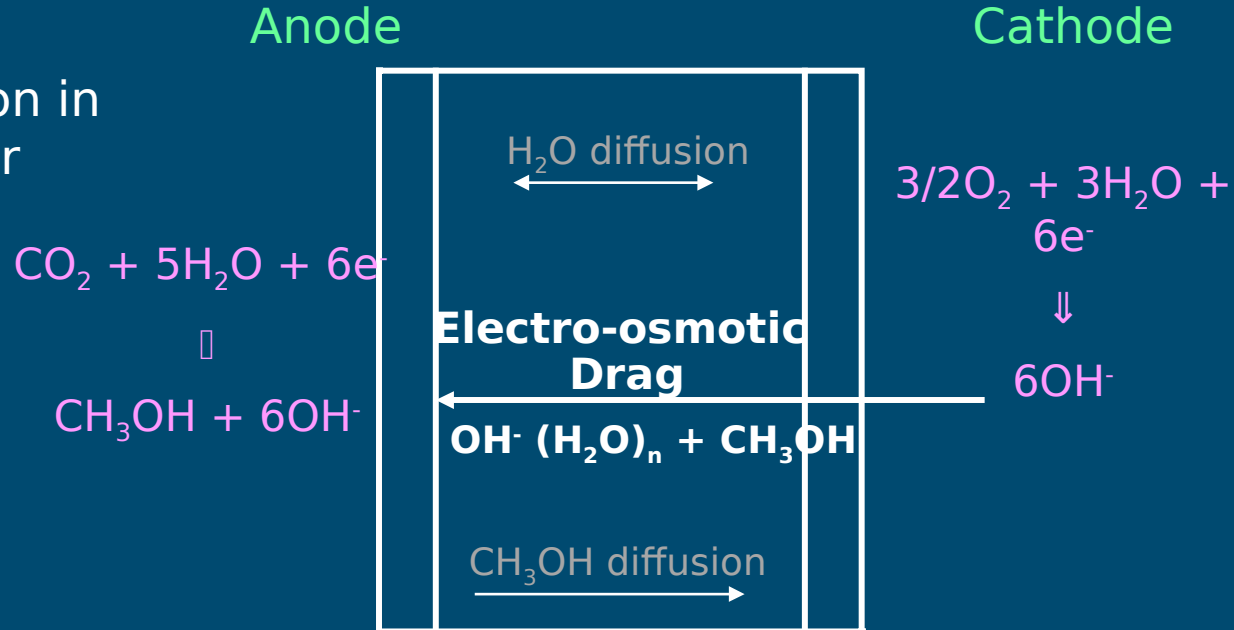
- H⁺ conducting polymer membrane eg Nafion

- Noble metal catalysts needed



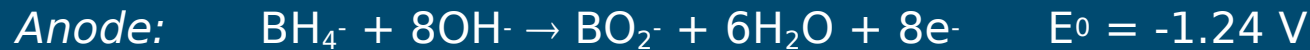
Alkali DMFC

- Electro-osmotic drag is towards the anode
 - Seven fold reduction in methanol crossover
- Catalysis is less problematic
 - Mn, Ag, Ni anodes
 - Co cathodes
- Carbonate poisoning?
 - Carbonate/bicarbonate buffers



Sodium tera-borohydride (NaBH_4) alkaline fuel cell (STBHAFC)

- Reactions



- Fuel

- theoretical capacity of pure STBH is 5661 Ah/ kg
- theoretical energy density is 9285 Wh/ kg cf 6200 Wh/kg for methanol
- STBH is soluble in aqueous media up to approximately 25 w/o

- Performance

- preliminary studies indicate a 20 fold increase in power over that obtained in our best DMFCs